ECC block design

CEA Saclay

03 March 2018

Emag design – New assumptions

Interbeam distance: 204 mm

High field strand diameter: 1.1 mm (for procurement reason)

Heat treatment dimensional change: +1% width ; +3% thickness

Yoke outer diameter: 570 mm (instead of 600 mm, enough room for the Al shell + SS shell)

Bore thickness: 1.9 mm, including 0.5 mm thick ground insulation
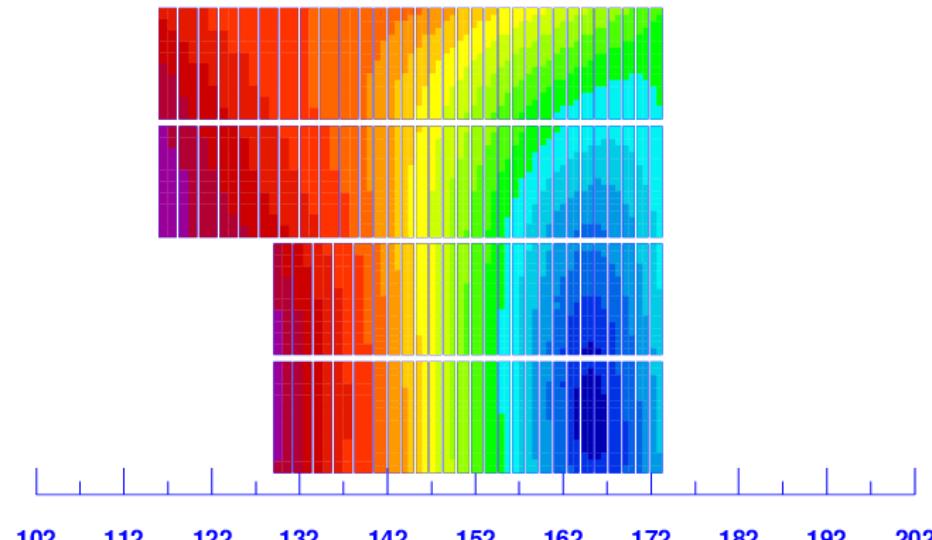
Space for He cooling 2xDN105 + 4xDN30

-> All of theses items lead to the same quantity of conductor than for the previous 194 and 204 inter-beam distance magnetic designs

2D design
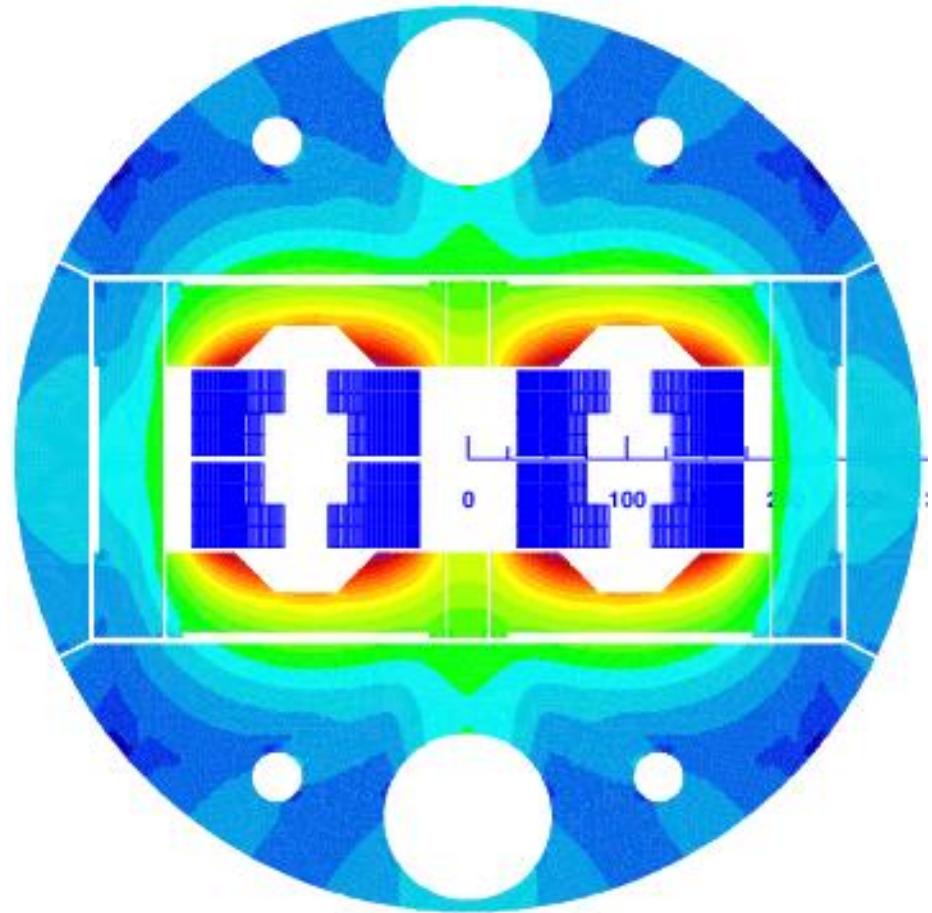
Quantity	v2ari204	v3ari204	v4ari204	Unit
strand diameter	1.1 – 0.7	1.1 – 0.7	1.1 – 0.7	mm
nb of strands	21 – 34	21 – 34	21 – 34	N/A
BE - Cable width	12.47	12.47	12.47	mm
BE - Cable thickness	1.94 – 1.23	1.94 – 1.23	1.94 – 1.23	mm
AF - Cable width	12.6	12.6	12.6	mm
AF - Cable thickness	2.0 – 1.27	2.0 – 1.27	2.0 – 1.27	mm
Cu/nonCu	0.8 – 2.0 (1.7)	0.8 – 2.0 (1.7)	0.8 – 2.0 (1.7)	N/A
I_{nom}	10090	10080	10123	A
B_{peak}	16.75	16.77	16.75	T
LL margin (1.9 K)	13.74	13.71	13.72	%
Inductance diff. (2 ap)	49.1	49.1	49.1	mH/m
Stored energy (2 ap)	2611	2599	2615	kJ/m
Nb of turns	116 = 5+5+10+10+21+21+22+22	116 = 5+5+10+10+21+21+22+22	116 = 5+5+10+10+21+21+22+22	-
Fx & Fy (per ½-coil)	8180 & -3520	x	x	kN/m
Hotspot	x	x	x	K
Bore thickness	1.9	1.9	1.9	mm
Midplane shim	2.4	2.35	2.35	mm
LdxI (1 aperture)	x	x	x	HA/m
I/Ic HF-LF	x	x	x	-
Out yoke diameter	600	570	570	mm
Conductor area (2 ap)	138	138	138	cm²
4578 x 14.3 x 8.7 weight	7860	7860	7860	tons

V3ari204 & V4ari204

102 112 122 132 142 152 162 172 182 192 202
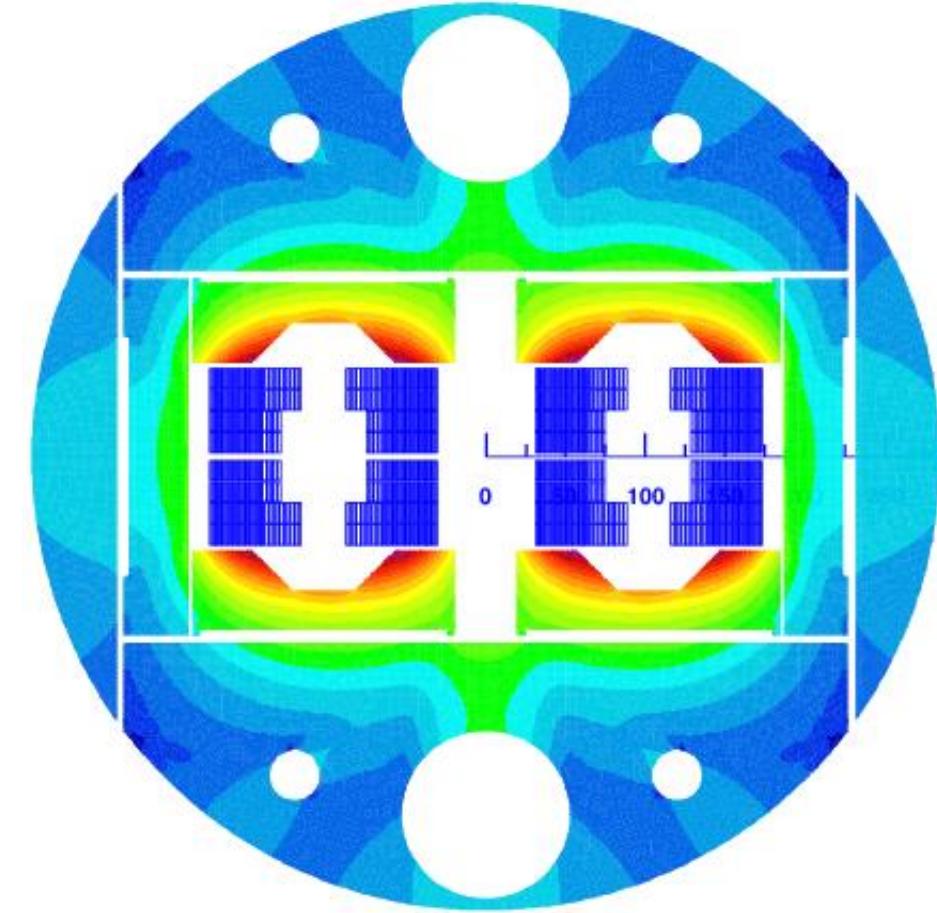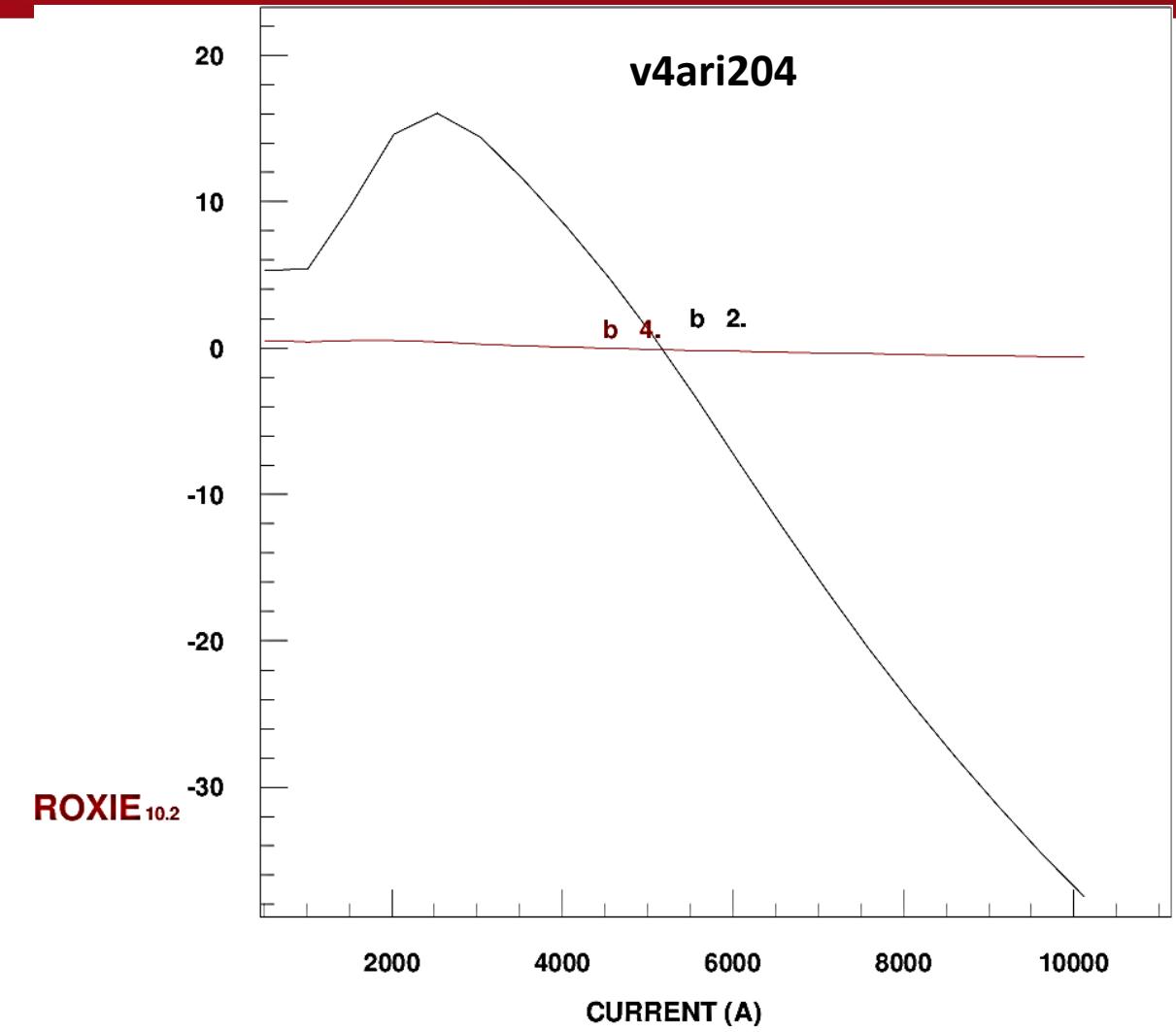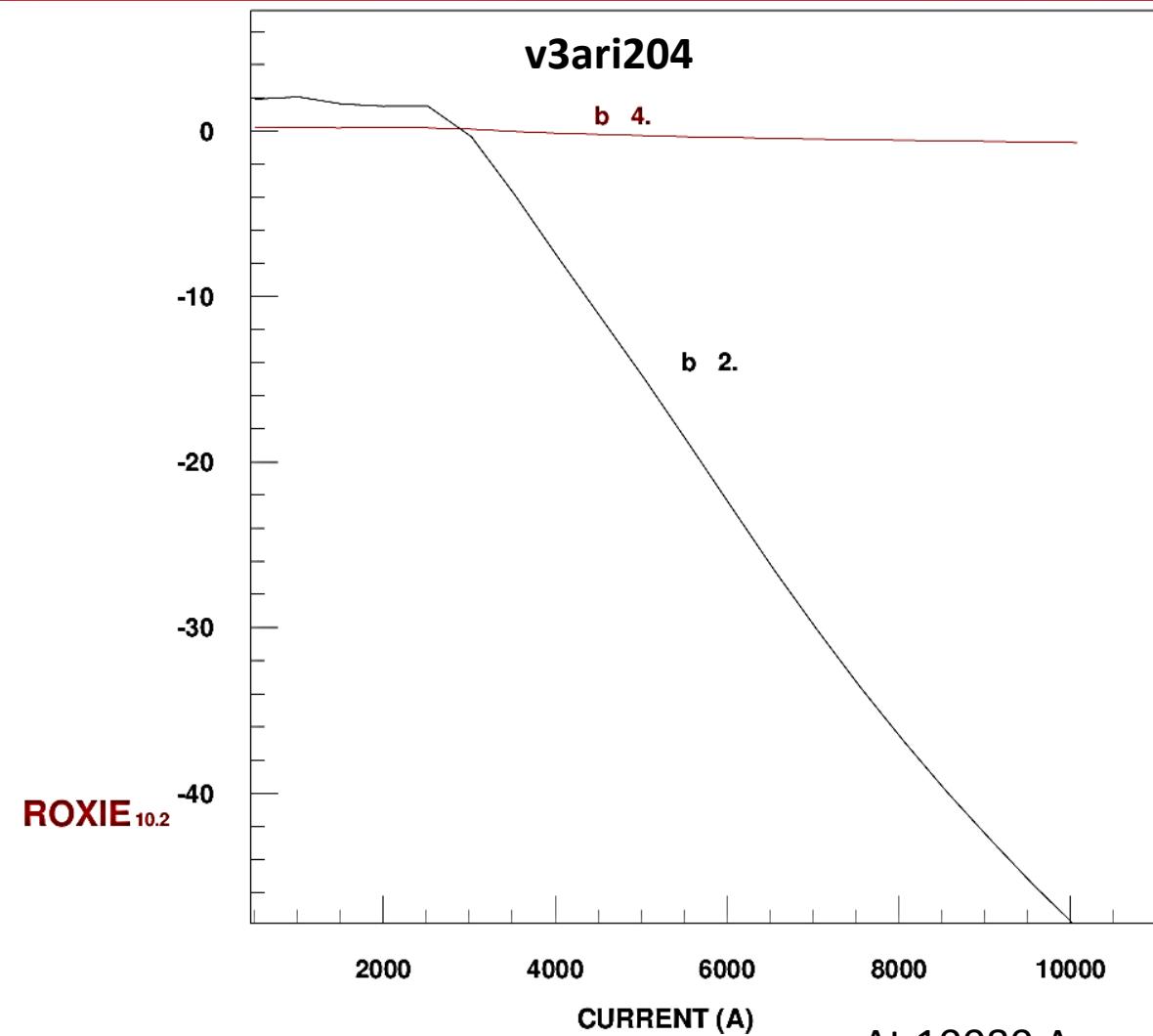
v3ari204

v4ari204
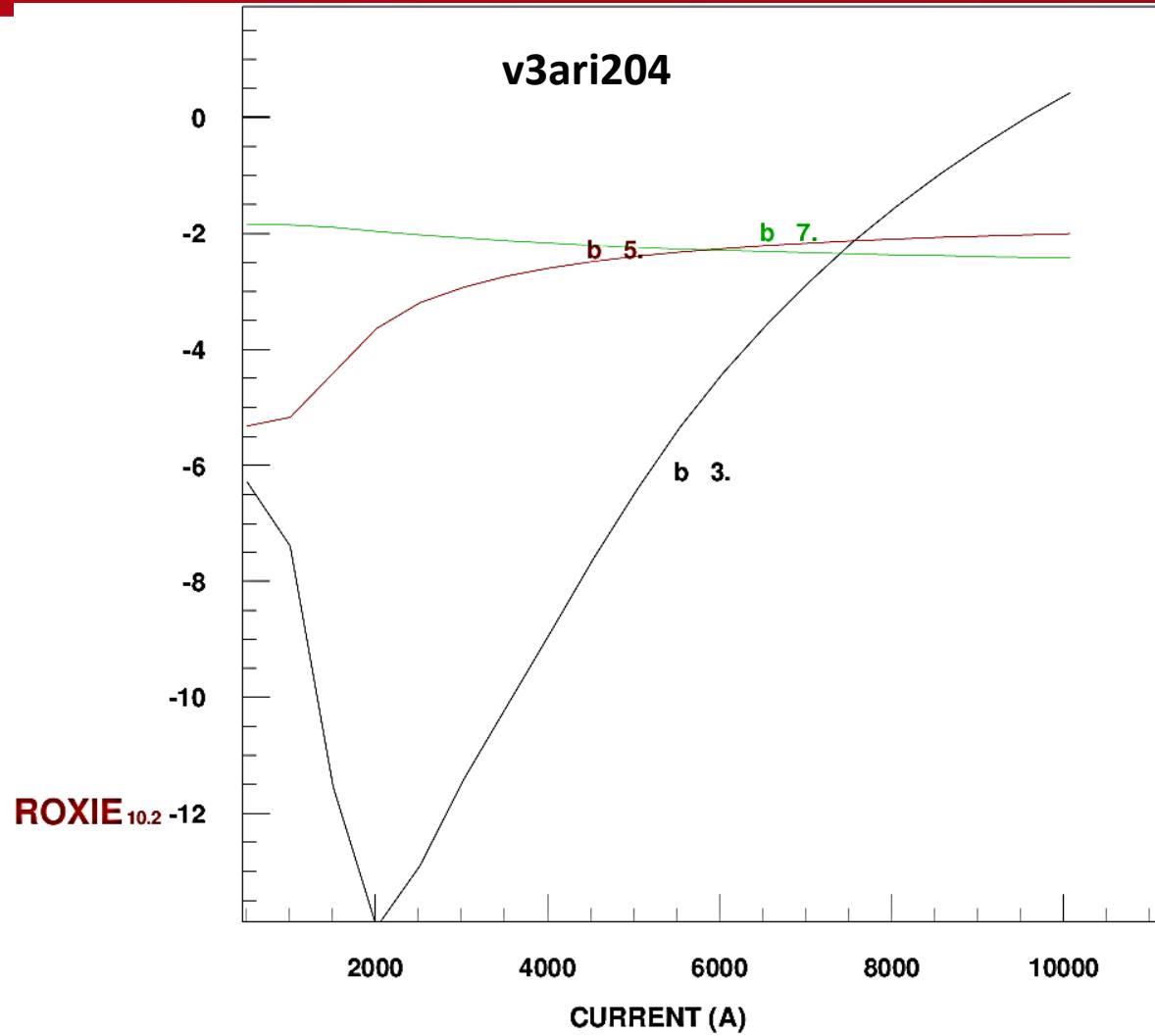
Yoke outer diameter: 570 mm
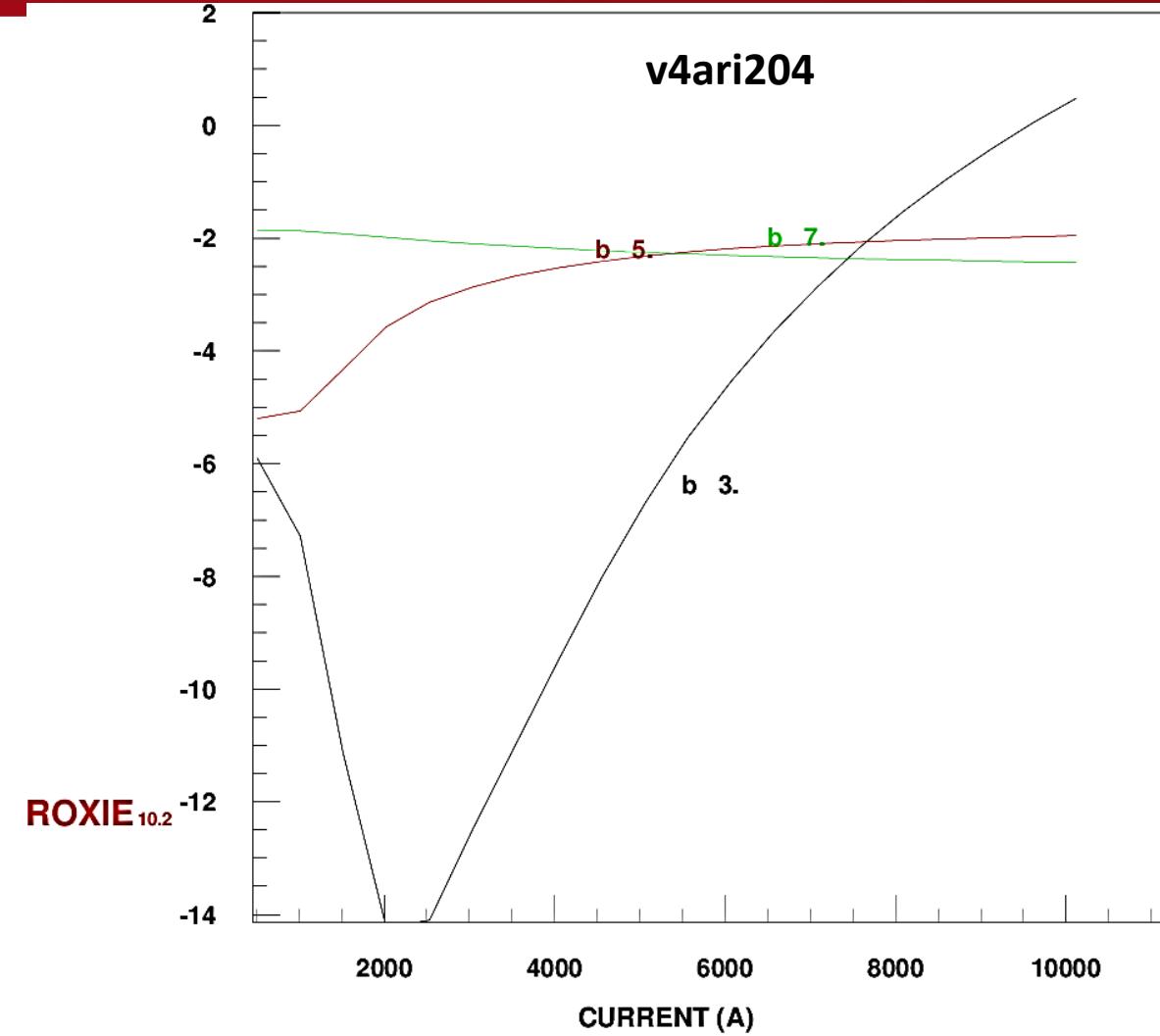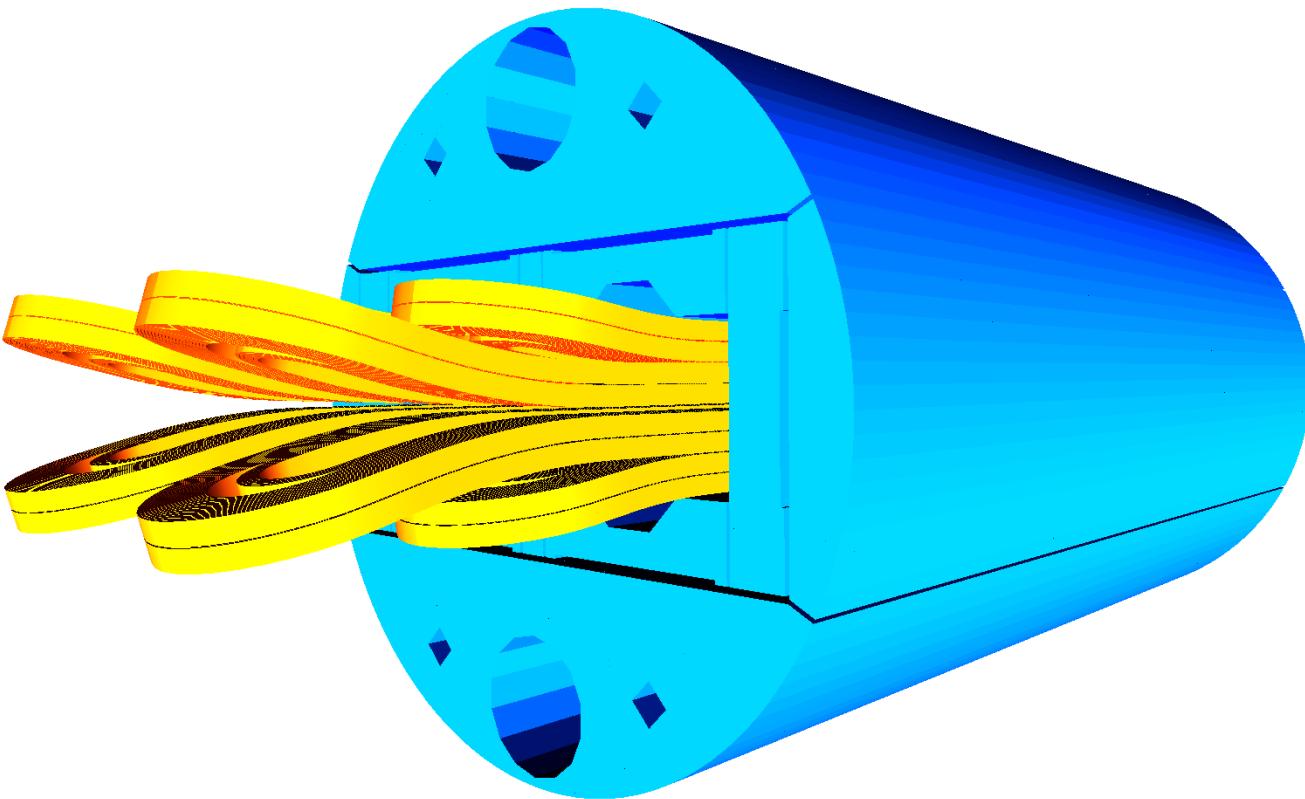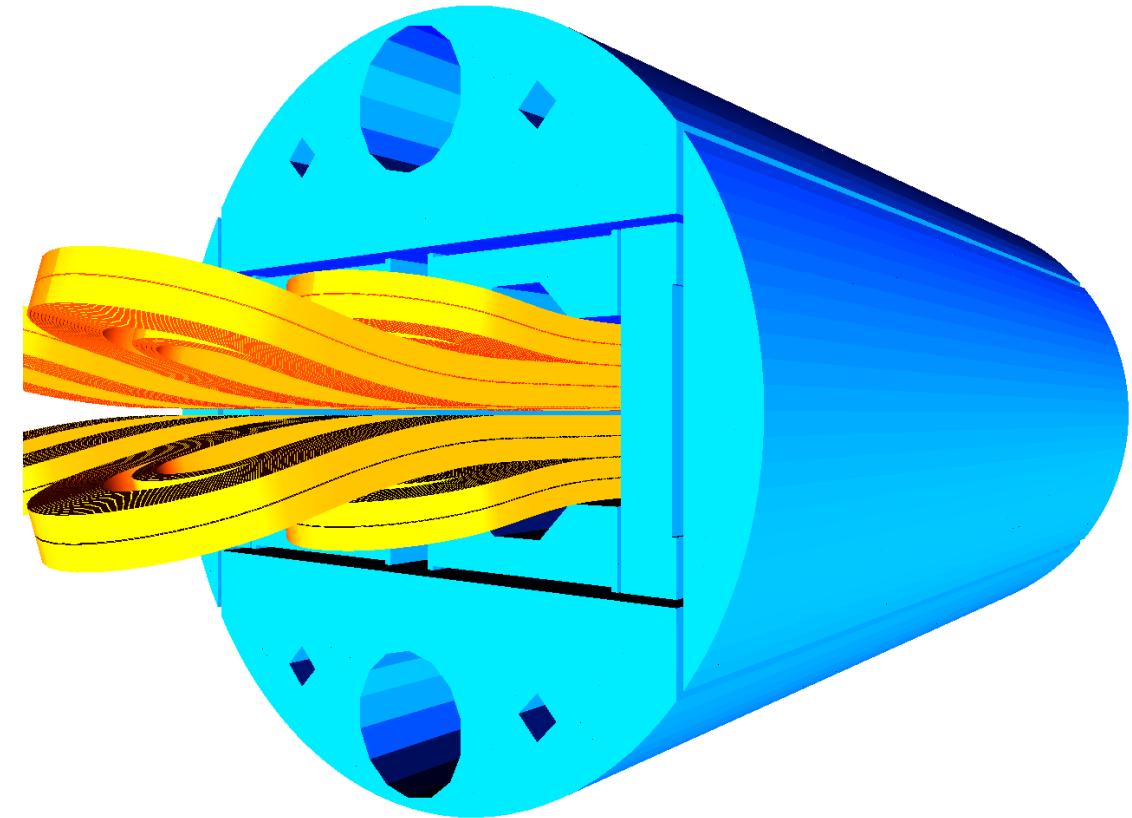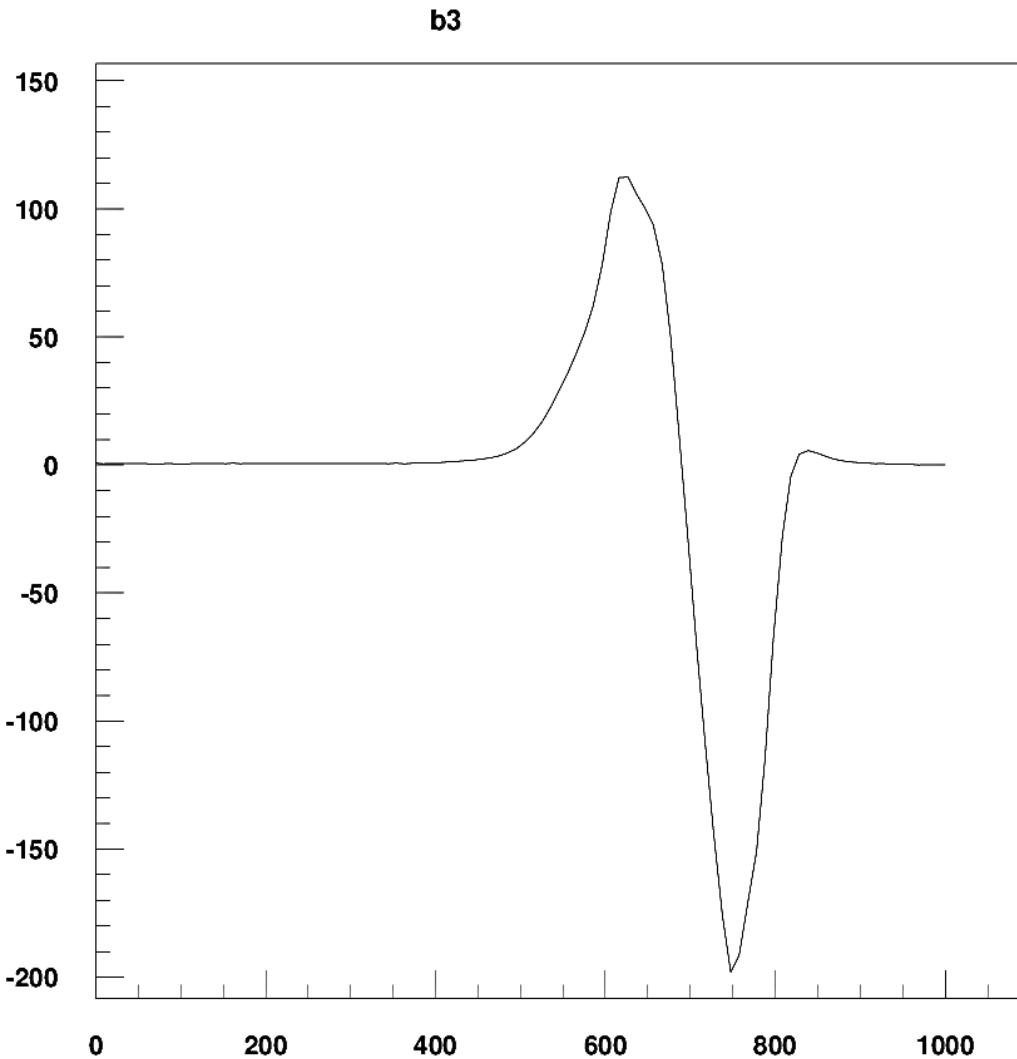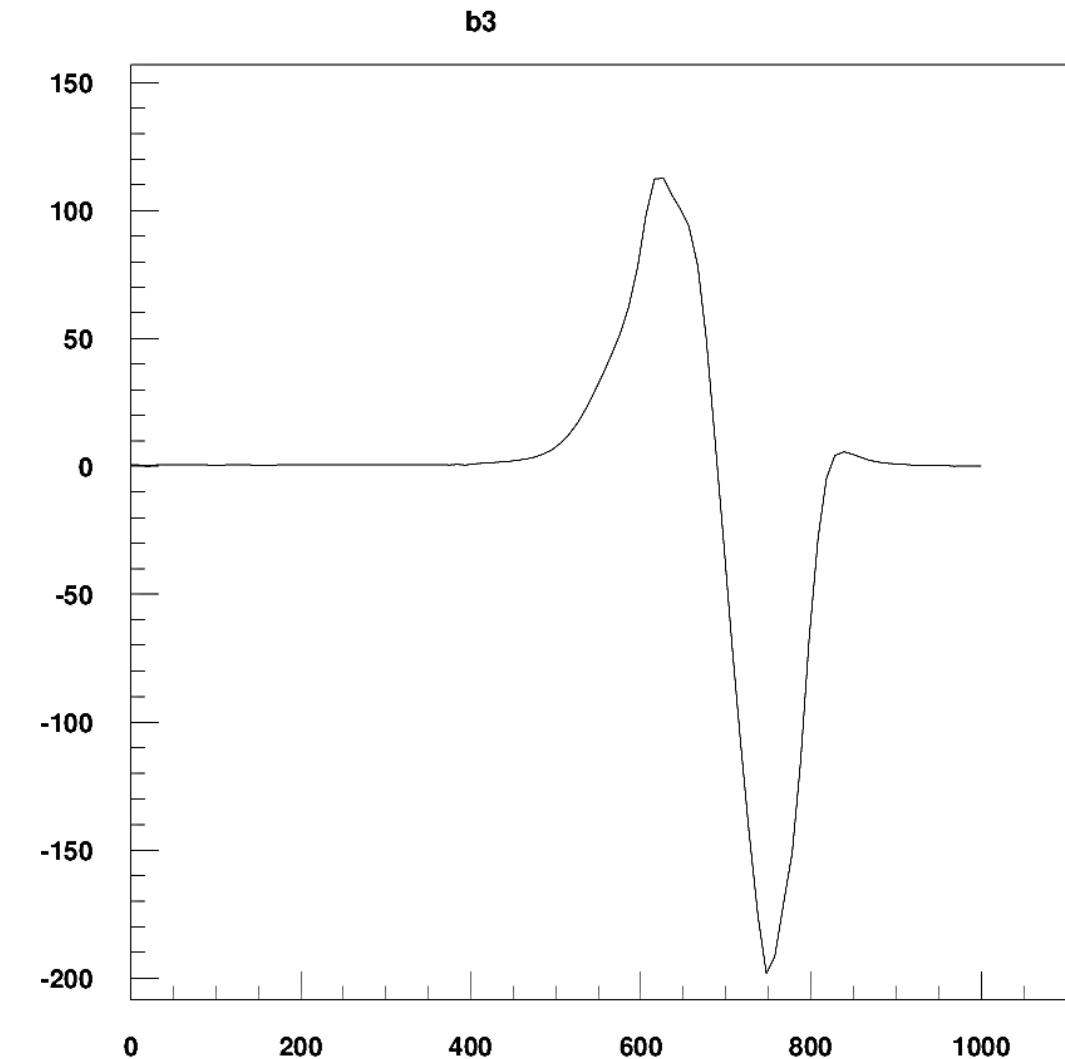
Harmonic content

v3ari204

At 10080 A

```
NORMAL RELATIVE MULTIPOLES (1.D-4):
b 1:  10000.00000  b 2:   -48.11305  b 3:    0.43399
b 4:     -0.70383  b 5:    -2.00884  b 6:   -0.00235
b 7:     -2.41937  b 8:     0.00011  b 9:   -1.58072
```


v4ari204

At 10123 A

```
NORMAL RELATIVE MULTIPOLES (1.D-4):
b 1:  10000.00000  b 2:   -37.48157  b 3:    0.48593
b 4:     -0.60352  b 5:    -1.95555  b 6:   -0.00676
b 7:     -2.42863  b 8:    -0.00002  b 9:   -1.58761
```

v3ari204

b 5.

b 7.

b 3.

ROXIE 10.2

At 10080 A

```
NORMAL RELATIVE MULTIPOLES (1.D-4):
b 1:   10000.00000   b 2:     -48.11305   b 3:        0.43399
b 4:      -0.70383   b 5:      -2.00884   b 6:       -0.00235
b 7:      -2.41937   b 8:       0.00011   b 9:       -1.58072
```


v4ari204

b 5.

b 7.

b 3.

ROXIE 10.2

At 10123 A

```
NORMAL RELATIVE MULTIPOLES (1.D-4):
b 1:   10000.00000   b 2:     -37.48157   b 3:        0.48593
b 4:      -0.60352   b 5:      -1.95555   b 6:       -0.00676
b 7:      -2.42863   b 8:      -0.00002   b 9:       -1.58761
```

v3ari204

v4ari204

v3ari204

v4ari204

b3

b3

v3ari204

```
ROXIE 2D

BLOCK NUMBER ............................................       54
PEAK FIELD IN CONDUCTOR   747 (T) ...................       16.7697
MAXIMUM LOADLINE IN BLOCK    54 (%) ................       86.2909
REFERENCE RADIUS (mm) ............................       16.6700
MAIN FIELD (T) .........................................      -16.001561
NORMAL RELATIVE MULTIPOLES (1.D-4):
b 1:  10000.00000  b 2:     -48.11305  b 3:       0.43399
b 4:      -0.70383  b 5:      -2.00884  b 6:      -0.00235
b 7:      -2.41937  b 8:       0.00011  b 9:      -1.58072


ROXIE 3D

REFERENCE RADIUS (mm) ............................       16.7000
3D REFERENCE MAIN FIELD (T) ....................      -15.9962
MAGNETIC LENGTH (mm) .........................       676.3968

NORMAL 3D INTEGRAL RELATIVE MULTIPOLES (1.D-4):
Version 1.29/04 of HIGZ started
b 1:  10000.00000  b 2:     -65.27112  b 3:      -3.71753
b 4:      -0.86286  b 5:      -6.79211  b 6:       0.00562
b 7:      -3.29996  b 8:       0.00604  b 9:      -1.53070


NORMAL INTEGRAL RELATIVE MULTIPOLES (1.D-4) ON 14 m (magnetic length):
b 2 = [12.64 x (-48.11) + 2 x 0.68 x (-65.27)] / 14.00 = -49.78 < 50 units
b 3 = [12.64 x 0.43 + 2 x 0.68 x (-3.72)] / 14.00 = 0.03     < 3 units
b 5 = [12.64 x (-2.01) + 2 x 0.68 x (-6.79)] / 14.00 = -2.47 < 3 units
b 7 = [12.64 x (-2.42) + 2 x 0.68 x (-3.30)] / 14.00 = -2.50 < 3 units
```

v4ari204

```
ROXIE 2D

BLOCK NUMBER ............................................       54
PEAK FIELD IN CONDUCTOR   747 (T) ...................       16.7697
MAXIMUM LOADLINE IN BLOCK    54 (%) ................       86.2909
REFERENCE RADIUS (mm) ............................       16.6700
MAIN FIELD (T) .........................................      -16.000277
NORMAL RELATIVE MULTIPOLES (1.D-4):
b 1:  10000.00000  b 2:     -37.48157  b 3:       0.48593
b 4:      -0.60352  b 5:      -1.95555  b 6:      -0.00676
b 7:      -2.42863  b 8:      -0.00002  b 9:      -1.58761


ROXIE 3D

REFERENCE RADIUS (mm) ............................       16.6700
3D REFERENCE MAIN FIELD (T) ....................      -15.9949
MAGNETIC LENGTH (mm) .........................       677.1459

NORMAL 3D INTEGRAL RELATIVE MULTIPOLES (1.D-4):
Version 1.29/04 of HIGZ started
b 1:  10000.00000  b 2:     -57.35904  b 3:      -3.70853
b 4:      -0.78462  b 5:      -6.71480  b 6:      -0.00603
b 7:      -3.27263  b 8:       0.00023  b 9:      -1.53180


NORMAL INTEGRAL RELATIVE MULTIPOLES (1.D-4) ON 14 m (magnetic length):
b 2 = [12.64 x (-37.48) + 2 x 0.68 x (-57.36)] / 14.00 = -39.41 < 50 units
b 3 = [12.64 x 0.49 + 2 x 0.68 x (-3.71)] / 14.00 = 0.08     < 3 units
b 5 = [12.64 x (-1.95) + 2 x 0.68 x (-6.71)] / 14.00 = -2.41 < 3 units
b 7 = [12.64 x (-2.43) + 2 x 0.68 x (-3.27)] / 14.00 = -2.51 < 3 units
```

**ACTUAL MODEL V3ari204
(interbeam distance = 204 mm)**

with outer yoke Ø = 570 mm

65 mm thick Al shell + 20 mm thick SS shell

Horizonthal keys → 2 x 0.67 mm ←

Vertical keys 50 µm ↓
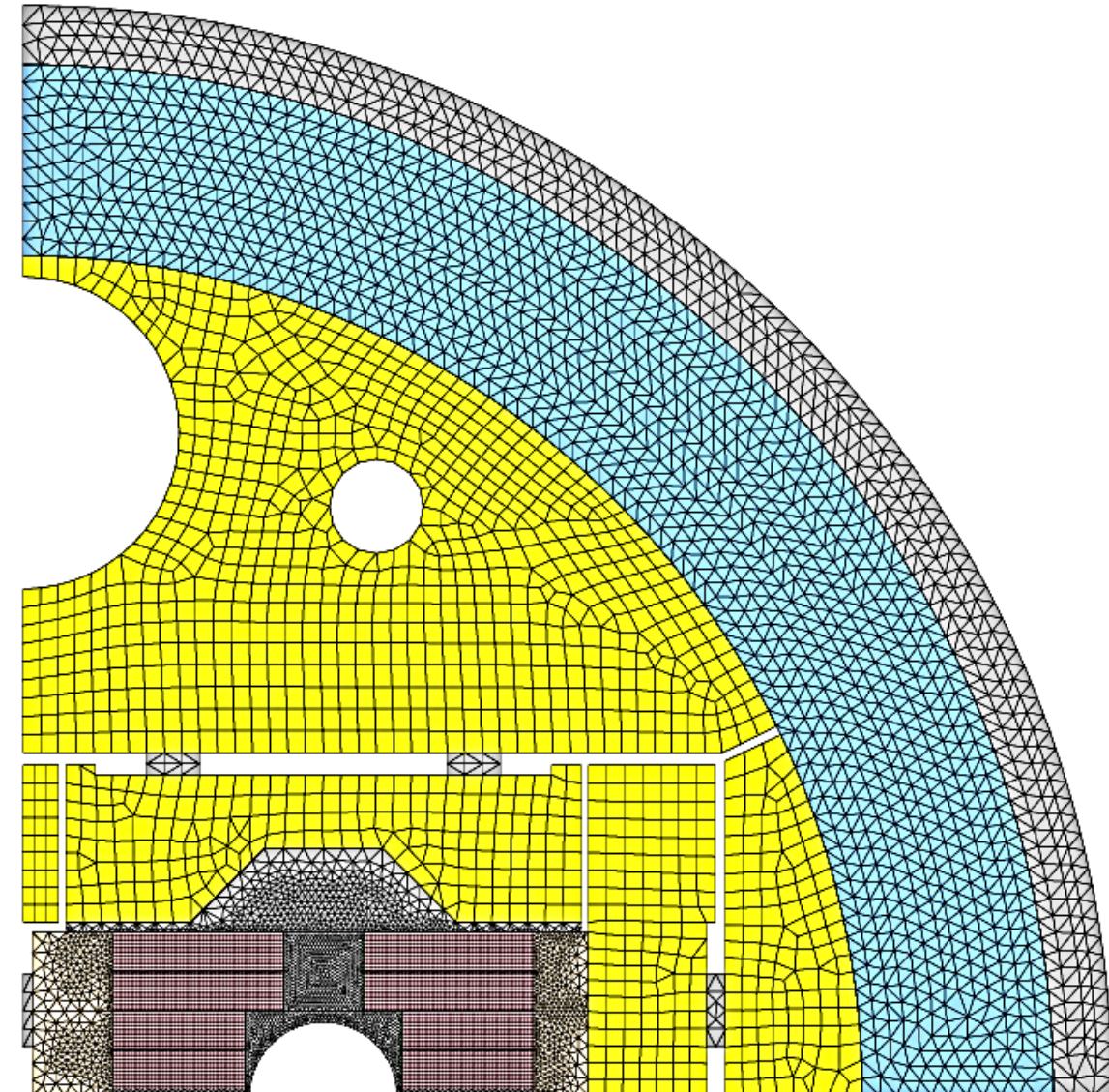
Imposed displacement on SS shell bottom:
-0.2 mm

Contacts/symmetry:

Sliding with possible separation; no friction
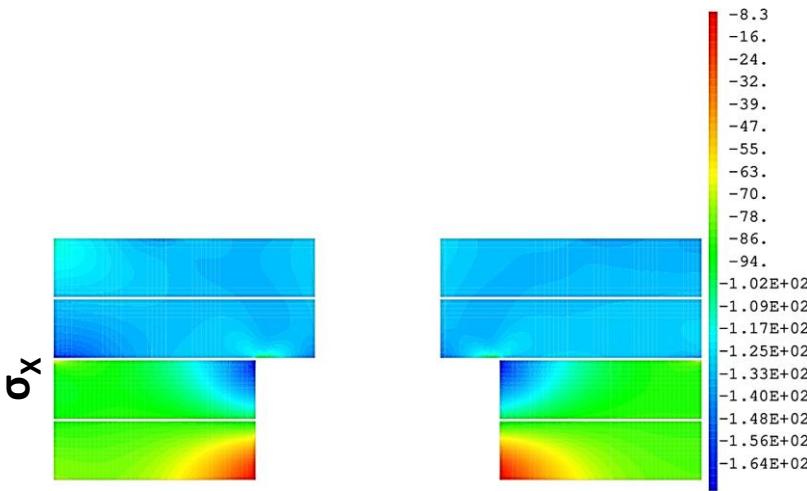
Coils glued with pole via a Kapton insulation

¼ of the structure (symmetries)

# Coil stress distribution

Key + SS shell **Cold – 4.2 K** **16 T**

σ_x

-170 MPa   -205 MPa   -188 MPa

von Mises
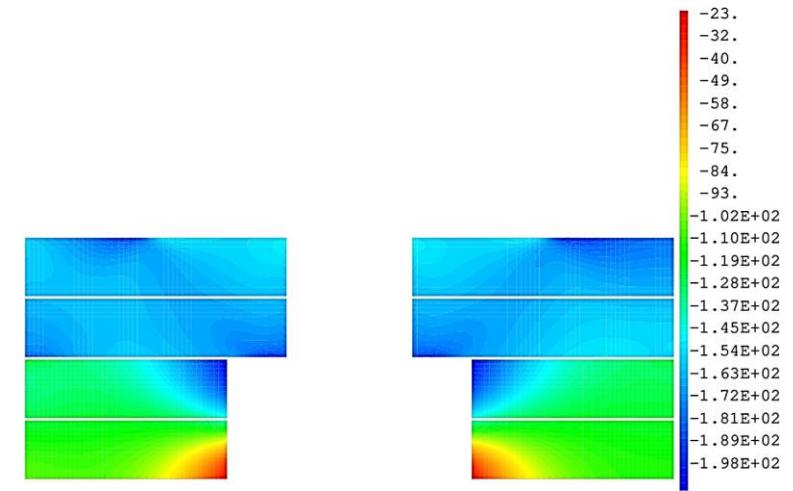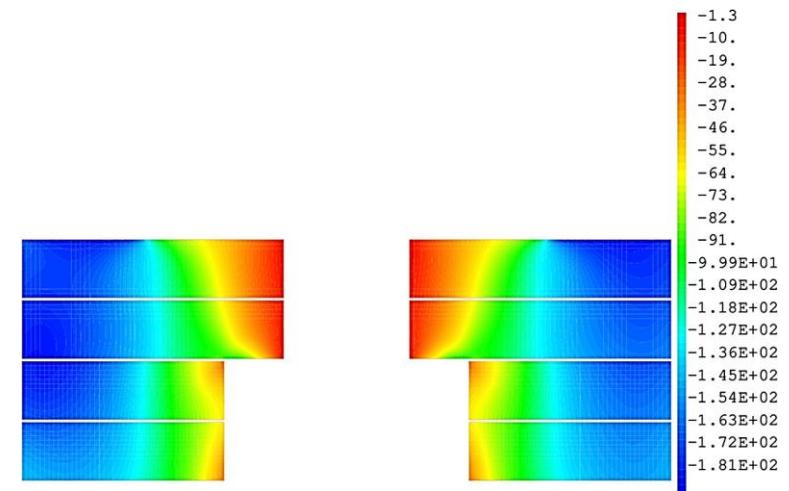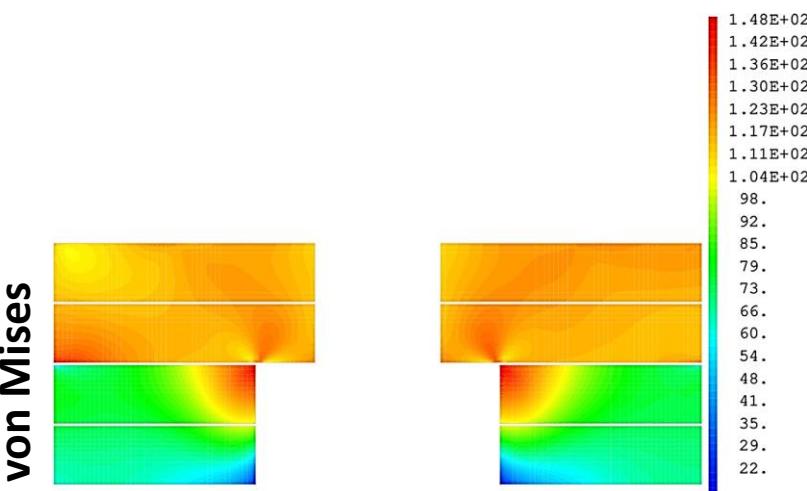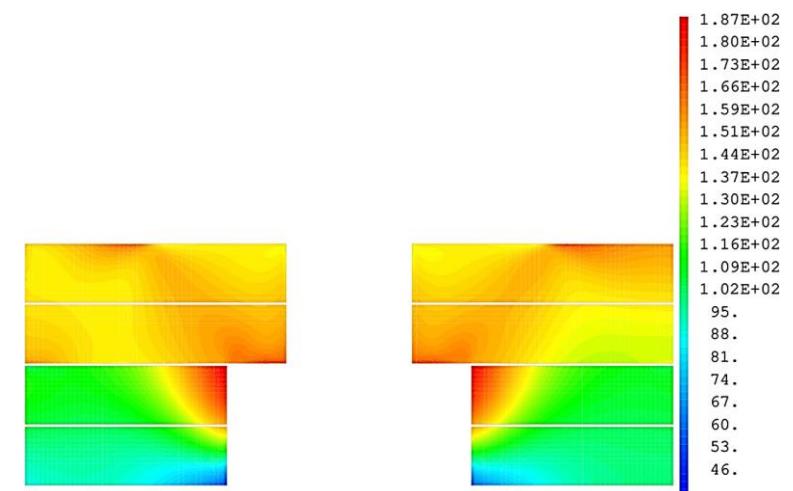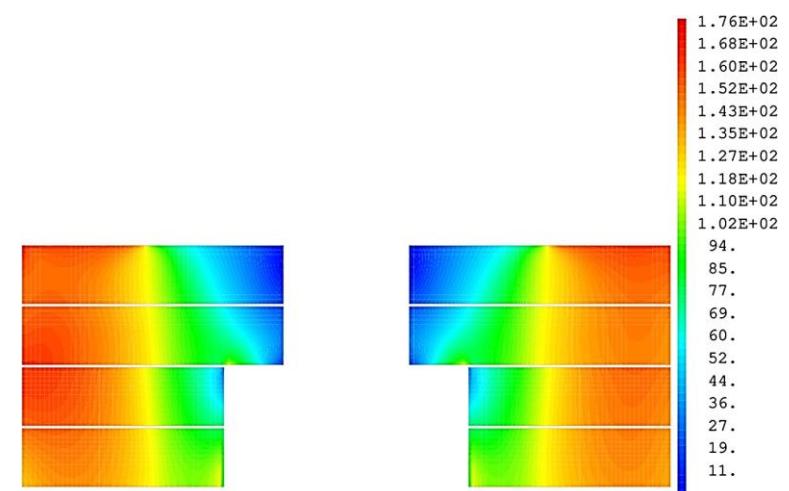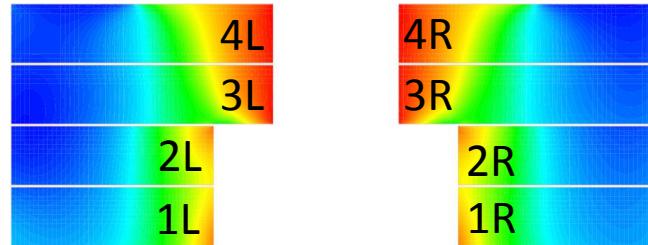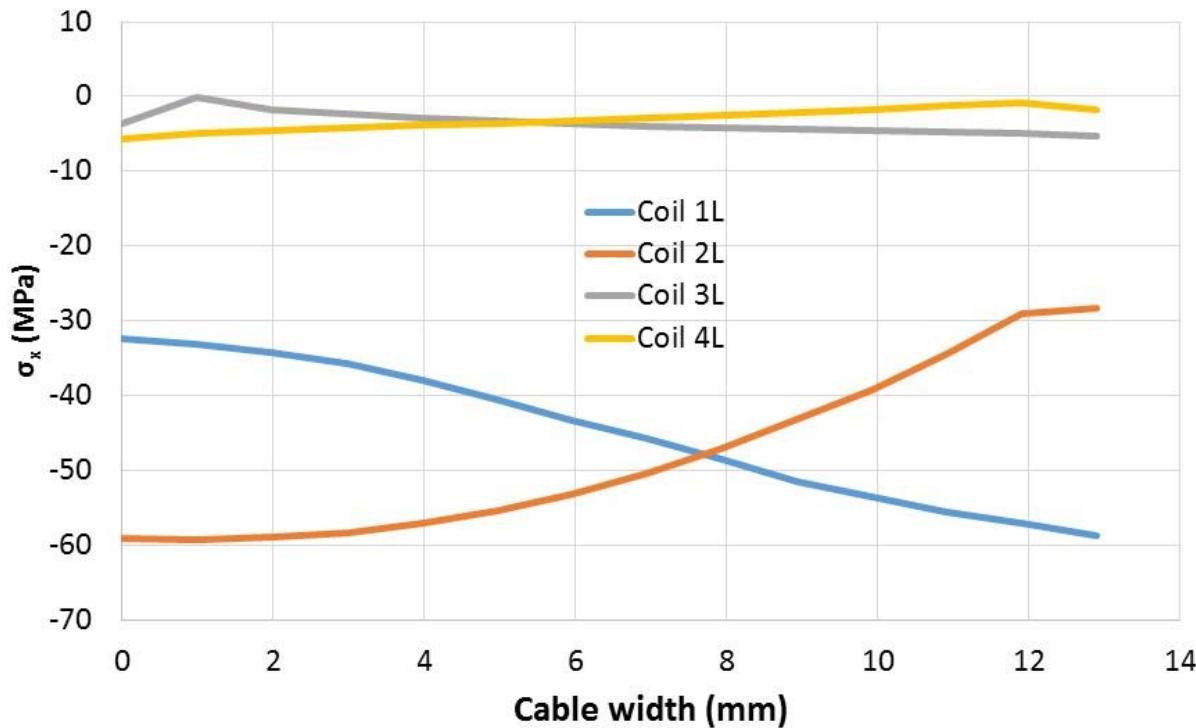
+149 MPa   +188 MPa   +178 MPa

σ$_x$ at coil / pole interface
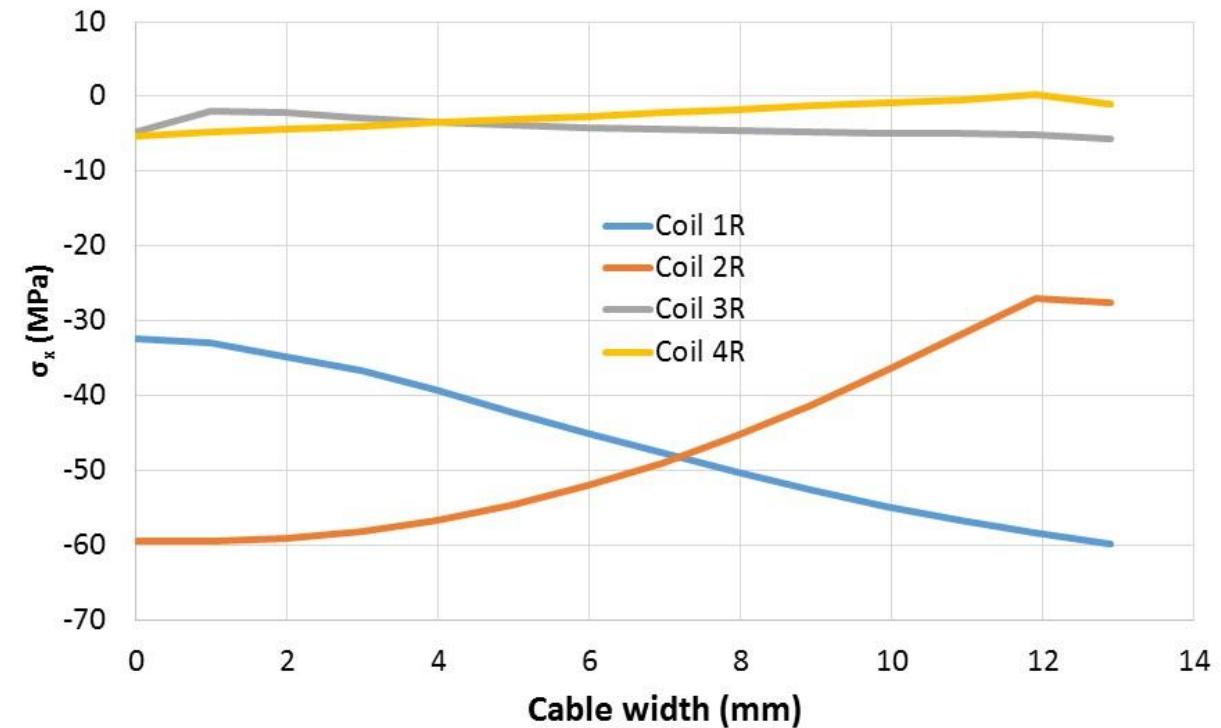
16 T
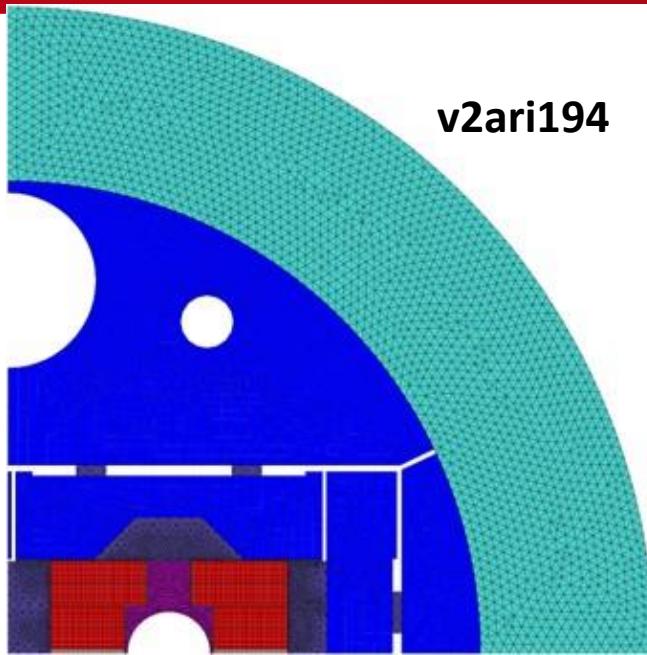
Synthesis

v2ari194
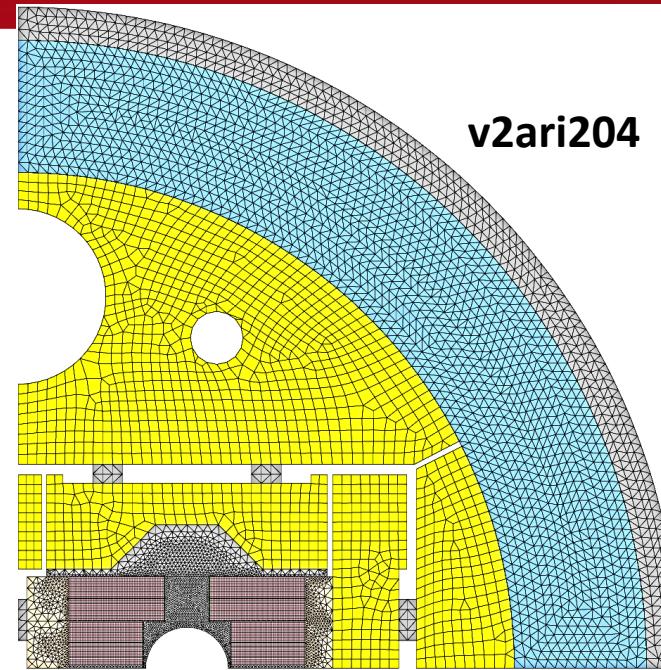
Interbeam distance = 194 mm
Ø$_{ext}$ iron yoke = 570 mm
Total Ø$_{ext}$ = 780 mm
105 mm thick shell
1.14 mm ←
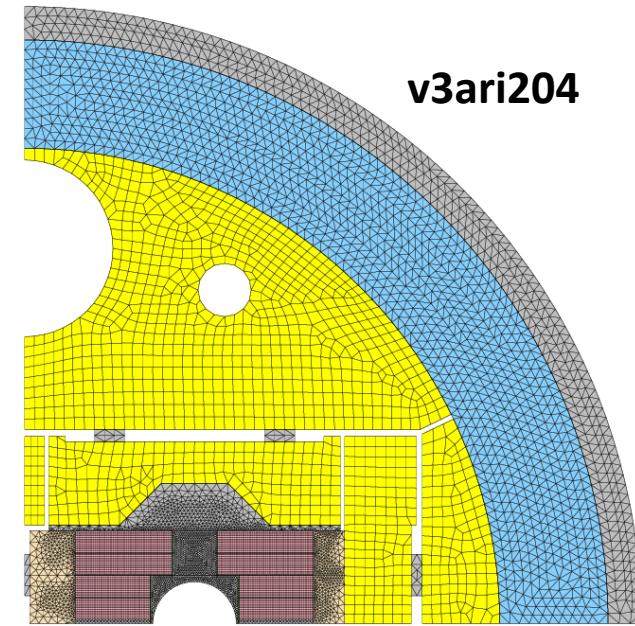
	σ$_X$ max	σ Von Mises max
Keys	-137	147
Cool-down	**-204**	181
Energization 16 T	-196	190

v2ari204

Interbeam distance = 204 mm
Ø$_{ext}$ iron yoke = 600 mm
Total Ø$_{ext}$ = 800 mm
80 + 20 mm thick shells
→ 2 x 0.58 mm ←

	σ$_X$ max	σ Von Mises max
Keys + SS shell	**-165**	145
Cool-down	**-204**	187
Energization 16 T	-194	182

v3ari204

Interbeam distance = 204 mm
Ø$_{ext}$ iron yoke = 570 mm
Total Ø$_{ext}$ = 740 mm
65 + 20 mm thick shells
→ 2 x 0.67 mm ←

	σ$_X$ max	σ Von Mises max
Keys + SS shell	**-170**	149
Cool-down	**-205**	188
Energization 16 T	-188	178

ACTUAL MODEL V4ari204
(interbeam distance = 204 mm)

with outer yoke Ø = 570 mm

65 mm thick Al shell + 20 mm thick SS shell

Horizonthal keys 1.51 mm ←
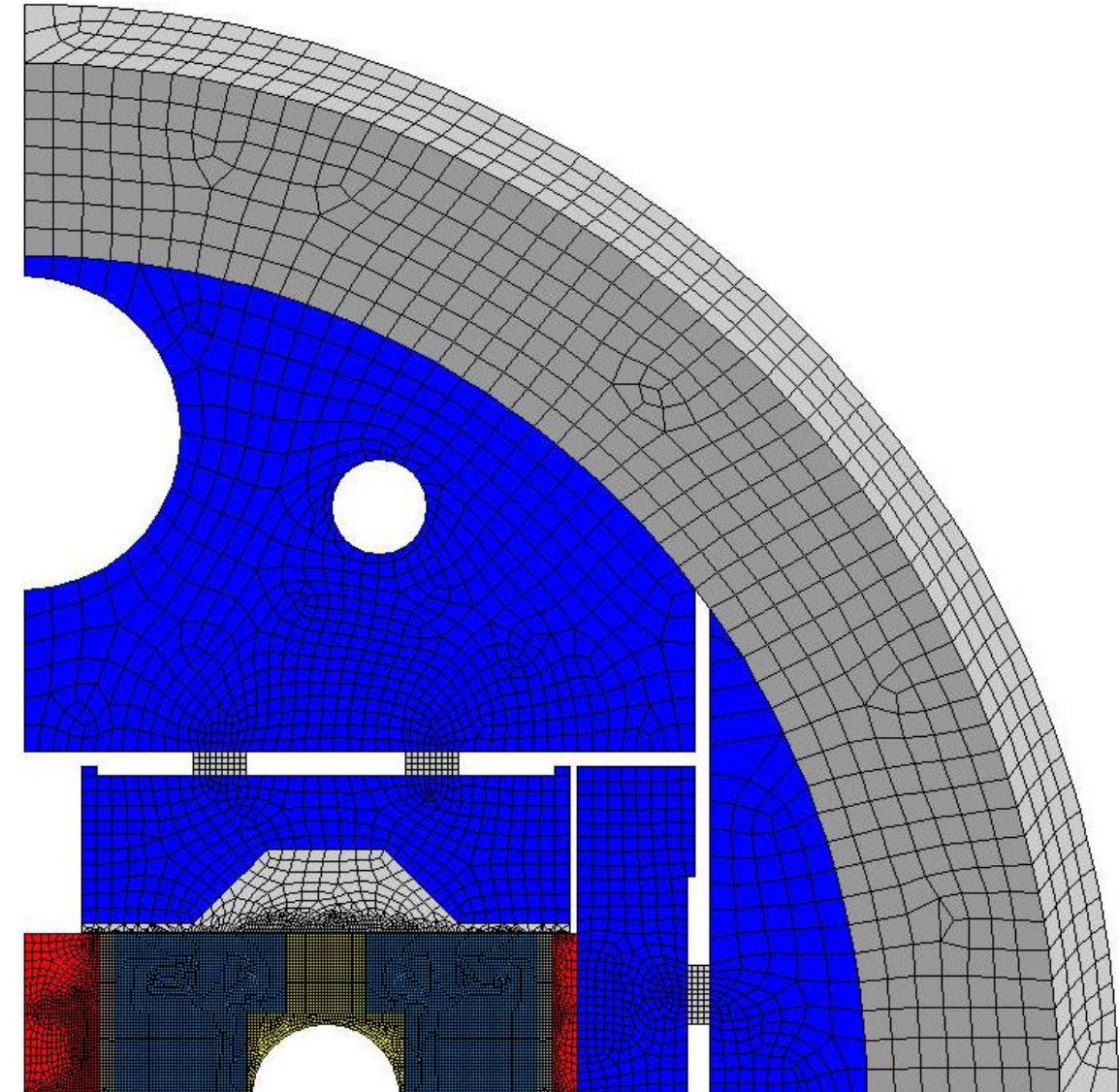
Vertical keys 100 µm ↓

Imposed displacement on SS shell bottom:
-0.2 mm
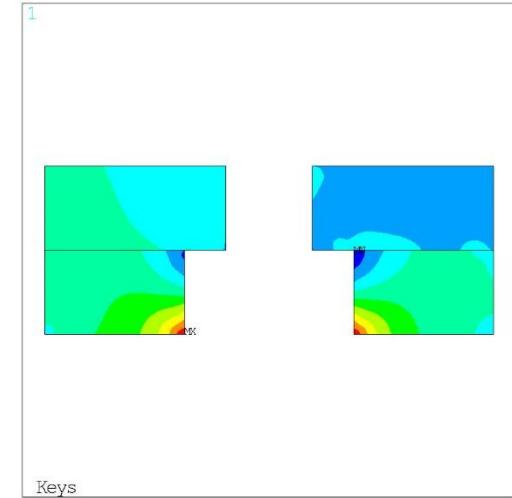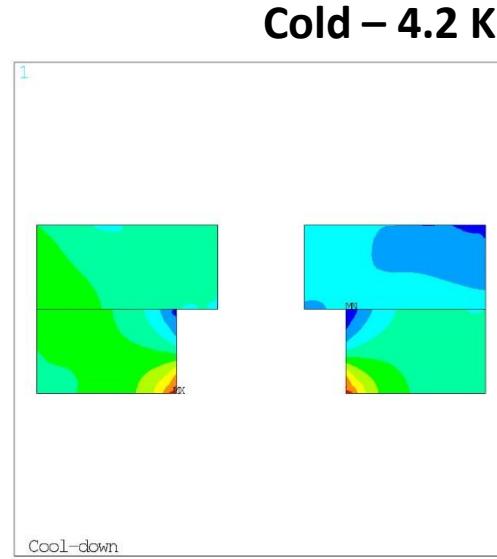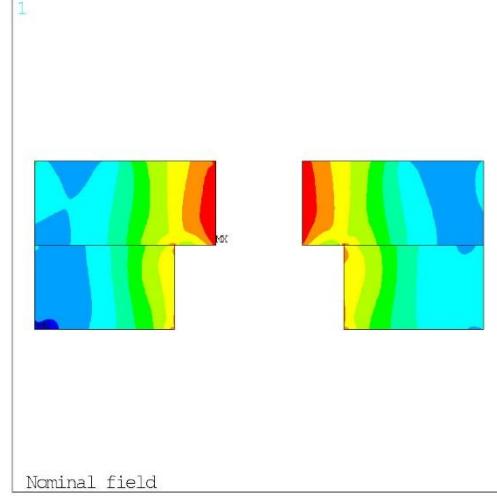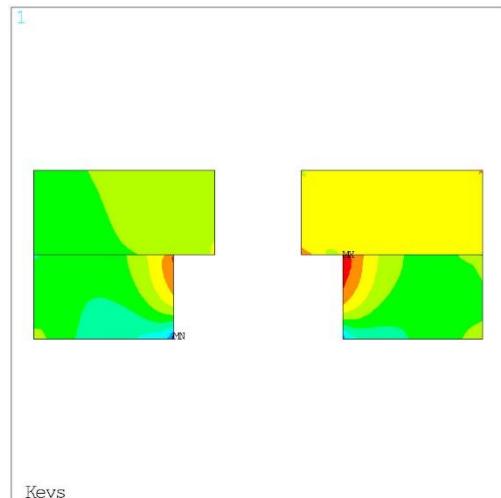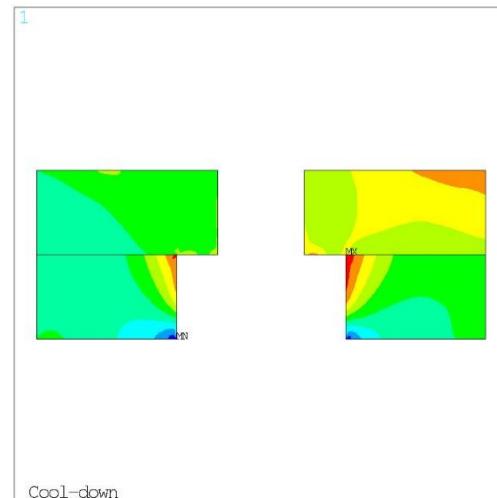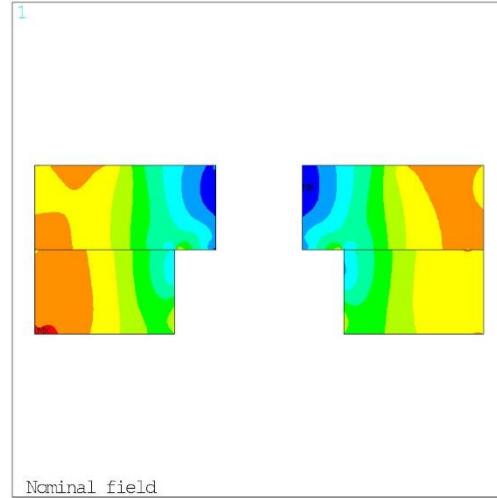
Contacts/symmetry:

Possible separation; friction
Coils glued with pole via a Kapton insulation
¼ of the structure (symmetries)
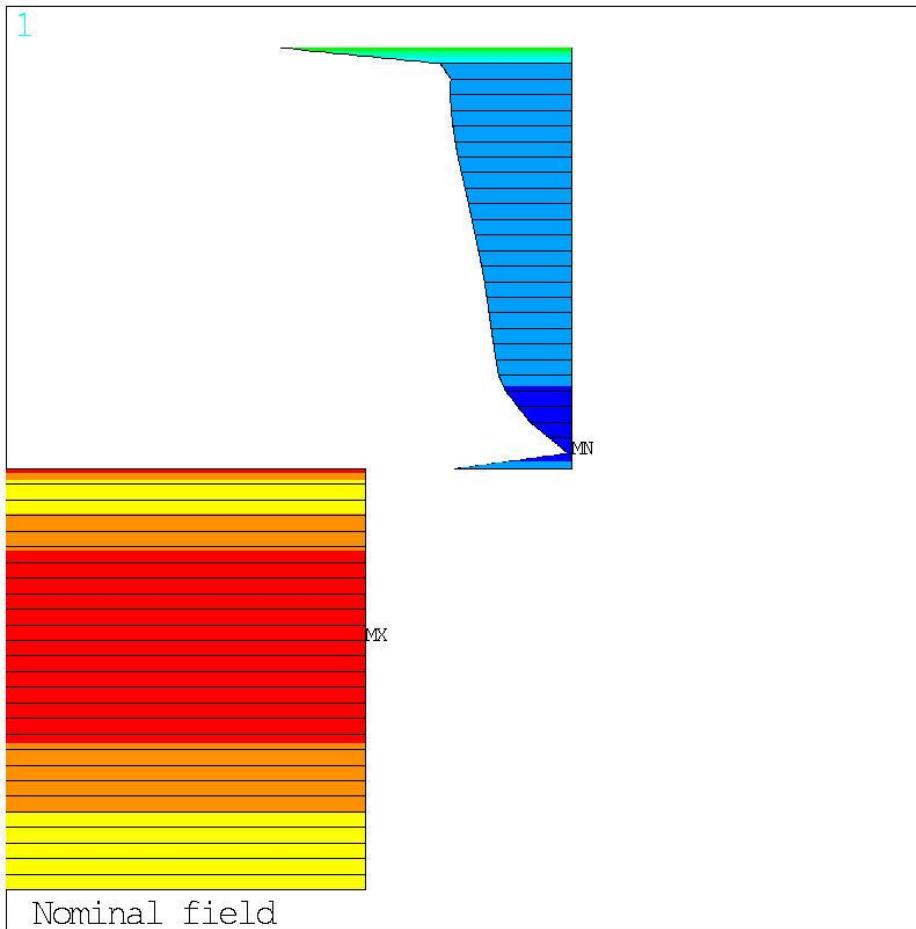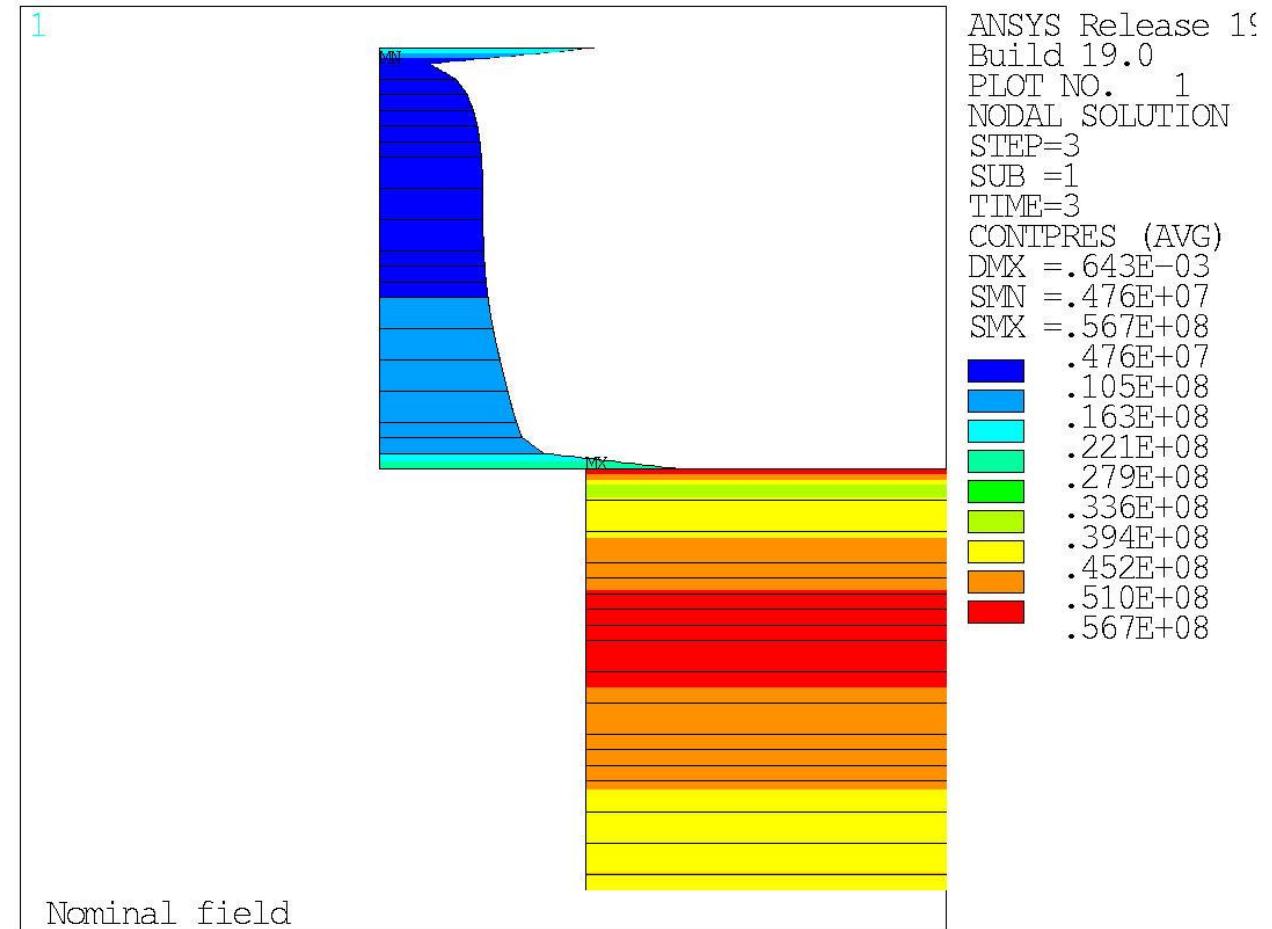
# Coil stress distribution

Key + SS shell **Cold – 4.2 K** **16 T**

σ_x
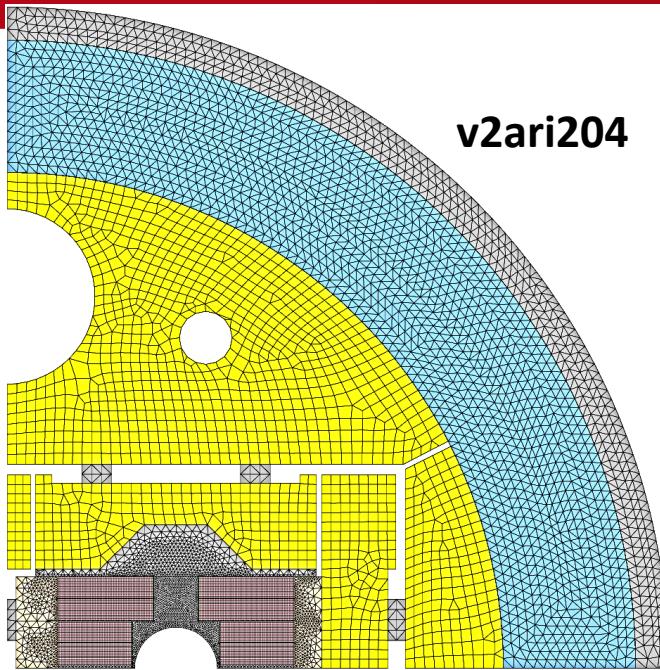
-135 MPa

-184 MPa

-214 MPa

von Mises


+123 MPa

+170 MPa

+186 MPa

σ$_x$ at coil / pole interface
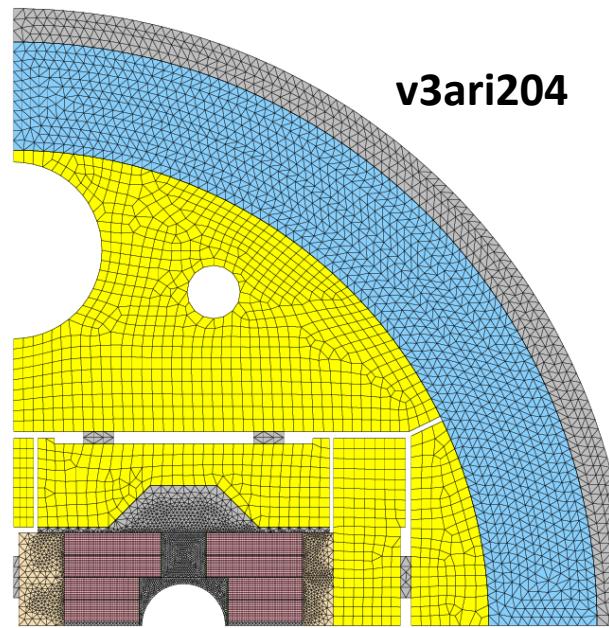
Synthesis

v2ari204

Interbeam distance = 204 mm
Ø$_{ext}$ iron yoke = 600 mm
Total Ø$_{ext}$ = 800 mm
80 + 20 mm thick shells
→ 2 x 0.58 mm ←

	σ$_X$ max	σ Von Mises max
Keys + SS shell	**-165**	145
Cool-down	**-204**	187
Energization 16 T	-194	182

v3ari204

Interbeam distance = 204 mm
Ø$_{ext}$ iron yoke = 570 mm
Total Ø$_{ext}$ = 740 mm
65 + 20 mm thick shells
→ 2 x 0.67 mm ←

	σ$_X$ max	σ Von Mises max
Keys + SS shell	**-170**	149
Cool-down	**-205**	188
Energization 16 T	-188	178

v4ari204
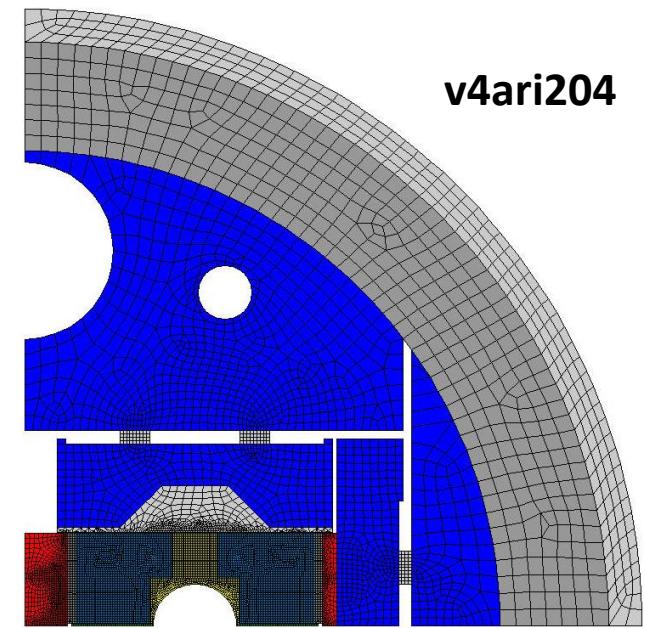
Interbeam distance = 204 mm
Ø$_{ext}$ iron yoke = 570 mm
Total Ø$_{ext}$ = 740 mm
65 + 20 mm thick shells
1.51mm ←

	σ$_X$ max	σ Von Mises max
Keys + SS shell	-135	123
Cool-down	-184	170
Energization 16 T	**-214**	186